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A Study of Total and Projected Root Surface Area of Extracted Maxillary Teeth from the Caucasion and Negro Population of North America

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A STUDY OF TOTAL AND PROJECTED ROOT SURFACE AREA OF EXTRACTED MAXILLARY TEETH FROM THE CAUCASION AND NEGRO POPULATION OF NORTH AMERICA

by

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AUTOBIOGRAPHY

Stephen M. Matokar was born in Chicago, Illinois on August 21, 1939. He graduated from Mt. Carmel High School in 1957 and began his undergraduate studies at St. Joseph's College, Rensselaer, Indiana.

In 1960, he entered Loyola University School of Dental Surgery and received the degree of Doctor of Dental Surgery in June, 1964.

After completing his dental education he entered the United States Navy as a commissioned dental officer in June of 1964. He served with the Marine Corps on Okinawa and Viet Nam.

Since June of 1966, he has been working toward a Master's Degree in the Department of Oral Biology at Loyola University, Chicago.

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CHAPTER I

INTRODUCTION AND STATEMENT OF THE PROBLEM

Introductory Remarks

Few investigators have attempted to correlate the total and projected root surface areas of teeth. These studies have established ratios which apply to the overall population.

The literature reveals that no attempt has been made to establish standard values or correlations for teeth according to individual races.

It may be concluded that it is necessary to achieve a clearer and more precise perspective in the biophysics of tooth movement. This research project will attempt to correlate the total and projected root surface area of the Caucasion and Negro teeth and in so doing attempt to provide a better understanding of the biophysics of tooth movement.

The roots of teeth vary in length, number and morphology. The roots are attached by the periodontal ligament to the alveolar bone. Smaller roots obviously have a smaller root surface to alveolar bone ratio than the larger roots.

Forces applied to the crowns of different teeth will not necessarily result in equal stresses to the alveolar processes. These forces which are distributed to the alveolar walls through the medium of the

periodontal ligament will be inversely proportional to the root surface area providing the force is constant. The forces applied to a tooth with a greater root surface area will place less stress against the periodontal ligament and alveolus than one with a smaller surface. The stresses which result from a force applied to the crown of a tooth are pressure, tension and shear.

The projected root surface area as defined by Jarabak and Fizzell (1963) is the "effective root surface area of a tooth on the pressure side", or "that area of the tooth which is adjacent to the bone if the tooth is to be moved bodily in that direction".

Statement of the Problem

The purpose of this project will be to attempt to measure the total and projected root surface area of maxillary teeth from the Caucasion and Negro population of North America and to determine if a correlation exists between them.

CHAPTER II

REVIEW OF THE LITERATURE

Hanau (1917) defined the projected root surface area as "that area in which the resisting pressure is uniformly distributed in the direction of the movement." He determined the projected root surface area of maxillary central incisors by means of theoretical mechanics, which may be reduced to simple mathematics.

Morelli (1927) considered the roots of teeth as geometric figures. For example, the maxillary central incisor was considered to be a cone, and by means of mathematical formulae he was able to determine the surface areas of various teeth.

Brown (1950) described a method of root surface measurements employing the so-called membrane technique. The root of the tooth was coated with a latex solution which after setting was peeled off as a membrane. This membrane was then laid on graph paper to determine the area. This method was not very precise because fractions of the squares had to be counted and recorded.

Phillips (1955) used the tin foil technique in measuring the root surface area of extracted anterior teeth. He filed the apicies of these teeth to simulate root resorption and adapted the tin foil to the root surface. He was able to measure the root surface area with a

planimeter after peeling the tin foil and laying it flat.

Boyd (1958) employed the membrane technique to determine the average periodontal area of molars, premolars, canines, and central and lateral incisors. His study of load and support was limited to the vertical loads upon the teeth and tissue and the support (root surface area) offered in resistance to these loads. He measured the average root surface area of five teeth in each category.

Tylman and Tylman (1960) gave values for the periodontal area in the entire dentition and compared this to the masticatory pressure. It was not stated how these values were reached and how many teeth were measured. Their values for the root surface area were much lower than those of Jepsen and Boyd.

Jepsen (1962) measured the root surface area of 238 extracted teeth using the membrane technique. The root was coated with a polyvinyl chloride solution, placed in an oven and allowed to polymerize for 30 minutes at 130° C. The tooth was slowly cooled, the membrane was peeled, laid flat, and photographed. The image was then enlarged five times, projected onto drawing paper, and the outline of the membrane drawn and measured with a planimeter. Jepsen also measured the root surface area by means of an x-ray photographic method and reported an accuracy of about 10 to 15%. The values of Jepsen and Boyd, are 25 to 55% higher than those of Tylman and Tylman.

Mc Laughlin (1962) devised a method of quantitating root substance, but his measurements were of volume and weight rather than actual root surface area.

Jarabak and Fizzell (1963) designated a parabola to represent the contour of a root and used integral calculus to mathematically derive the projected root surface area of a tooth. They worked primarily with the mandibular canine. Using this knowledge of projected root area with coordinates, they were able to find the centroid of a given tooth. Jarabak and Fizzell concluded that the root pressure was the most important factor in the determination of tooth movement and not the force applied to the crown of the tooth.

Freeman (1965) measured the root surface area of 330 extracted teeth using the membrane technique. The roots were coated with an air-cured latex material and measured with a compensating polar planimeter. His study was related to anchorage preparation in a typical four premolar extraction treatment program using the Begg technique. Therefore, the four first premolars were not included in his study.

Moromisato and Emmanuelli (1967) directed their investigation toward the determination of effective root surface area of each tooth as well as total root surface area of the maxillary and mandibular teeth.

A sample of 120 maxillary and mandibular teeth were selected at random and coated with a formvar material which could be air-cured. The membrane was peeled, laid flat and measured with a compensating polar planimeter to measure the total root surface area. They were able to measure the projected root surface area by photographing the teeth from the buccal and mesial surfaces. They obtained results similar to those of Jepsen and Boyd.

Schwarz (1932) found that the most favorable treatment utilized forces not greater than the capillary pressure. This pressure is 15 to 20 mm. Hg, or approximately 20 to 26 gms/cm^2.

The results of Orban (1936) paralleled those of Schwarz. He stated, "there is an optimum force necessary for the biologic tooth movement and that excessive forces crush the periodontal ligament". To what extent the damage occurs depends on the individual and his age.

Stuteville (1937) found that in some cases 150 to 200 grams of pressure produced no injury, while in others resorption was produced with much lighter forces. He concluded that the amount of force is not as important as the area covered by the force. The greater the area, the less the tendency to injury.

Moyers and Bauer (1950) agreed with Orban and concluded that a force in excess of 25 gm/cm^2, when ideally the force should be 15 to 25 gm/cm^2, will diminish the blood supply to the periodontal ligament

and thus induce a pathological change in those areas. Further, it is desirable to have this force be intermittent in order that the periodontal membrane may enjoy periods of recovery.

Renfroe (1951) referred to "effective root surface area" when he suggested that only a portion of the root surface area is involved at any one time in resisting the movement of the tooth in the direction of the force. He found in studying cross-sections of tooth roots that there are three general designs; round, triangular and oblong. These variations in design indicate that resistance to movement can be increased by form. The tooth with a purely round root when moved bodily presents 50% of its periodontal ligament fibers to resist the movement and relaxes about the same number. The tooth with a triangular cross-section presents a flat surface against the direction it was intended to resist and provides at least two thirds of its periodontal ligament fibers to increase the resistance. The oblong rooted tooth presents flat surfaces to the direction in which resistance is not needed.

Storey and Smith (1952) realized that it is not just the physical force that moves the tooth, but rather the pressure of that force and how it is distributed along the entire root surface area. They concluded, that an optimum range of 150 to 200 grams of force should be

used to produce a maximum rate of movement of the cuspid tooth without movement of the anchor unit. It is to be expected that this range will vary from patient to patient because of differences in age, sex, and root surface or projected root surface areas of the teeth. They stated, "Undoubtedly it is not the force that is exerted on the tooth that is significant, but rather the pressure (i.e., force/unit area) which is exerted at the interphase of the teeth, periodontal ligament, and bone. It is the pressure and its distribution over the surface of the root that will be difficult to estimate for various appliances and this could limit their proper design."

Mac Ewan (1954) found that in several distocclusion cases where intermaxillary elastics were used, the mandibular teeth were undisturbed throughout the length of treatment. He concluded that where tooth movement is desired, the light forces used exceeded the stability limit, but did not exceed the capillary blood pressure which is 20 to 25 gm/cm^2. Where tooth movement is not desired (that is, for anchorage), the force is kept below the stability limit which is about 7 gm/cm^2 of root surface.

Reitan (1957) found that a greater force per square millimeter of root surface area would tip the tooth rather than translate it. He also found that if the force magnitudes are equal, there is greater injury

to the bone when the teeth are tipped and uprighted than when they are moved bodily or translated.

Ricketts (1958), suggested the effectiveness of root surface area when he tried to move a lower second molar deliberately against the compact bone of the external oblique ridge and was unsuccessful. He stated, "I firmly believe that the cortical bone and the shape of a tooth resists the pull of elastics or the movement of the tooth."

Weinstein and Haack (1963) constructed a two-dimensional wooden model of a maxillary central incisor with an elastic foam sponge in the space between the root and alveolar process to simulate the means by which the application of forces to the crown of a tooth initiates a distribution of stresses in the periodontal ligament. They stated, "It is the nature of this distribution which determines the pattern of bone resorption and apposition and thus, the whole complex geometry of tooth movement."

Jarabak and Fizzell (1963) concluded that the only physiological explanation for tooth movement is, "the pressure per square millimeter of effective root surface area of that tooth." From this information they subdivided the root pressure necessary for tooth movement into three catagories:

1. Supramaximal pressure at which undermining resorption occurs.

2. Average root pressure needed to start translation of a tooth.

3. Subliminal pressure below which all movement ceases.

Dempster and Duddles (1964) concluded that the force vectors, "force couple on the crown" and "oblique or transverse forces to the crown" acting on different parts of the roots, attack them at specific angulations, at or in particular regions, and with varying magnitudes. They also determined that the magnitude of one of the reaction forces on the roots at the apices or alveolar margins may be nearly as great as the force applied to the crown.

CHAPTER III

METHODS AND MATERIALS

A. Selection of Membrane Material

Investigators have used many techniques in appraising the root surface area of teeth. Tin foil, polyvinyl chloride, polyvinyl alcohol and formvar have been utilized and formvar has been found to be the most accurate, pliable, and efficient.

Formvar (Polysciences, Inc.) was selected for this study since it was easy to use, could be air-cured, was dimensionally stable and durable, and could be readily peeled away from the root of the teeth. The most practical use of the formvar was its ability to be very accurately painted onto the bifurcation and trifurcation of multirooted teeth and peeled away without sticking or tearing. Since formvar in a liquid form is colorless, a blue black dye was added to facilitate the photographing of the membrane. The solution was made by mixing 5 grams of powder with 50 ml of 1,2 ethylene dichloride and allowed to dissolve overnight. Then the 2 grams of blue black dye was added to the 50 ml of formvar solution giving it a dark blue color.

B. Selection and Preparation of the Sample Teeth

A total of 180 maxillary teeth were used in this study. Ninety of

these teeth were from the Caucasion population and ninety were from the Negro population. Second and third molars were excluded and all first premolars were birooted.

Explicit instructions were given to the dentists and oral surgeons to keep the sample teeth in separate, specially labeled containers in-order to eliminate error in collecting the sample teeth. The extracted teeth were collected from the Department of Oral Surgery Loyola University, Fantus Clinic of Chicago, Cook County Hospital and from dentists and oral surgeons practicing in the Chicago area.

Particular emphasis was placed on the following points:

1. The tooth must be readily identified.
2. The root must be free of macroscopic pathological changes.
3. The roots of the teeth must be completely developed and intact.
4. The cemento-enamel junction must be clearly defined.

The remanents of the periodontal ligament were removed with a sharp scapel. The roots were then polished with pumice and a rag wheel. This facilitated removal of the formvar material from the root surface. Once cleaned of all debris the teeth were placed in a bleaching solution overnight and then stored in a 10% formalin solution.

C. Photographing Technique and Equipment

To eliminate possible error, stabilization of the equipment was given special attention. A special transilluminating view box was constructed with a frosted glass top to diffuse the light rays and give a more even source of light. The view box was made of hard wood and measured 12" x 10" x 9". The light source was a tensor light with a 15 watt bulb. The view box enabled the operator to record an accurate picture of the teeth and membranes without distortion due to shadows. The clear background made the object readily discernable and therefore easier to measure (Figure 1).

A rigid stand with an adjustable camera holder was made to accommodate a Nikkormat camera with a micro-Nikkor Auto 1:35 f=55mm lens. The camera attachment was adjustable in all planes enabling the operator to maintain a constant distance between the object to be photographed and the film, eliminating refocusing. A Honeywell spot light meter was used to determine the intensity of the light. Two tensor lamps were placed one on each side of the transilluminating view box at an angle of 45° to supply the additional light.

A strobe ring light around the camera lens provided the light when photographing the projected root surface area of the tooth. When photographing the total root surface area of the membrane, the source of light was from within the transilluminating view box plus the tensor

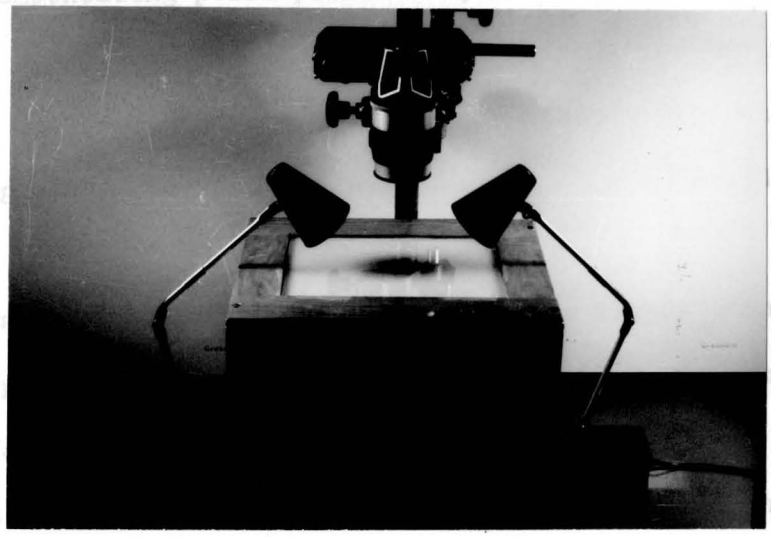

FIGURE 1

TRANSILLUMINATING AND PHOTOGRAPHING

APPARATUS

light on either side of the box. The ring light was not used.

D. Procedure:

1. Measurement of the Projected Root Surface Area

The teeth were photographed using Kodak Plus-X-Pan film. A Keuffer and Esser compensating polar planimeter, number 62000 was used to measure the projected root surface area (Figure 2). The instrument is designed to measure the area of irregularly shaped objects. The selected teeth were given an identifying letter and number code and separated by race.

The cemento-enamel junction was clearly outlined with a fine lead pencil and placed on the view box perpendicular to the camera. The mesial surface (projected root surface area) of the tooth was photographed. A reference square made by the Cameron-Miller Instrument Co., was photographed with the teeth and membranes (Figure 3).

The mesio-buccal root of the maxillary first molar was sectioned at the trifurcation allowing the mesio-buccal, disto-buccal and lingual projected root surface areas to be photographed with the 55mm auto Micronikkor lens in a 1:1 ratio (Figures 4 & 5).

The film was developed, dried, and the picture enlarged three times. The photographic image of the roots as well as the reference square were measured with the compensating polar planimeter.

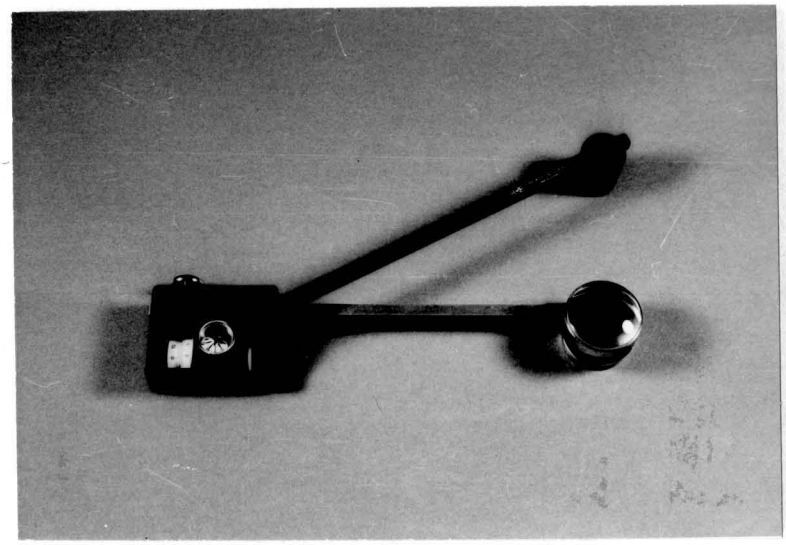

FIGURE 2

COMPENSATING POLAR PLANIMETER

FIGURE 3

BUCCO-LINGUAL PROJECTED ROOT SURFACE AREA

OF CANINE

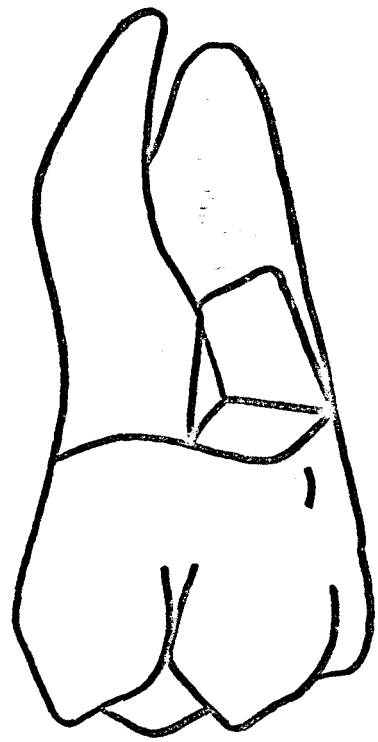

FIGURE 4

BUCCAL VIEW. SECTIONING OF MOLAR ROOTS

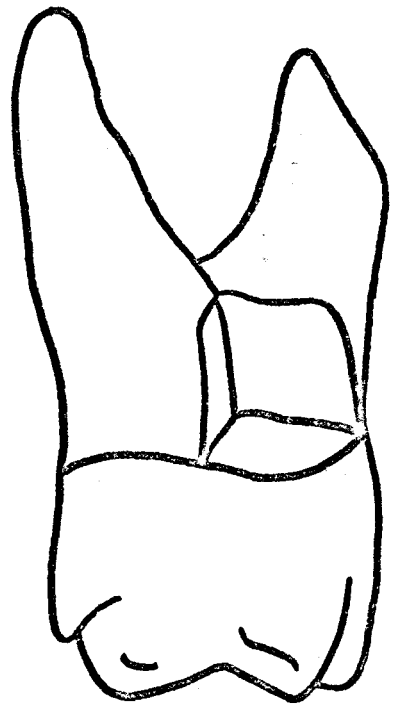

FIGURE 5

MESIAL VIEW. SECTIONING OF MOLAR ROOTS

The projected root surface area was calculated using the following formula:

$$\text{Projected Root Surface Area} = \frac{\text{Measured projected Root surface area} \times \text{Actual Area of square}}{\text{Measured Area of Square}}$$

2. Measurement of the Total Root Surface Area

The cemento-enamel junction of each tooth was clearly outlined with a fine pencil. The root was coated with a thin layer of Formvar solution and cured for 30 minutes. When completely cured, the membrane was cut from the cemento-enamel junction to the apex and peeled from the root. Additional cuts were made where necessary to assure that the membrane would lie flat. They were then placed on a glass slide. The reference square was placed beside the membrane and a photograph was taken (Figures 6,7 & 8). The photographic image of the membrane and reference square were measured and recorded. The square, membrane, and total root surface area was measured three times and recorded. An average of the three readings was recorded.

The total root surface area was calculated from the following formula:

$$\text{Total Root Surface Area} = \frac{\text{Measured Total Root surface area} \times \text{Total Area of square}}{\text{Measured Area of Square}}$$

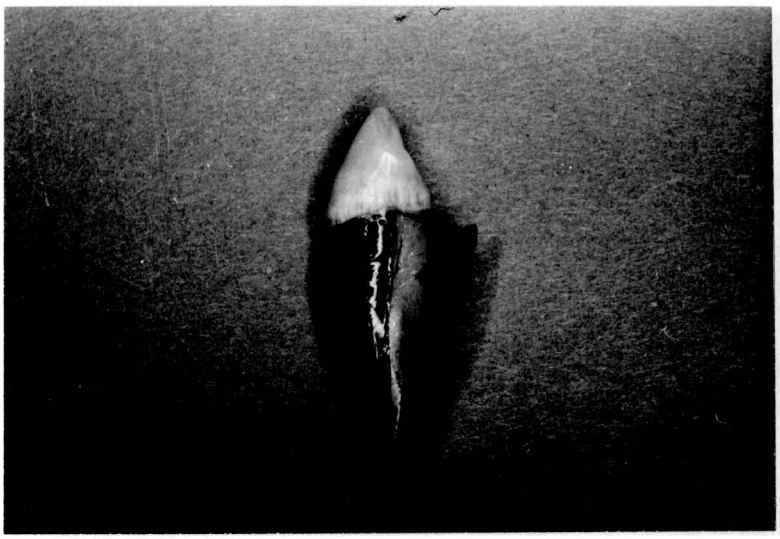

FIGURE 6

FORMVAR MEMBRANE ON CANINE

FIGURE 7

PEELING OF MEMBRANE

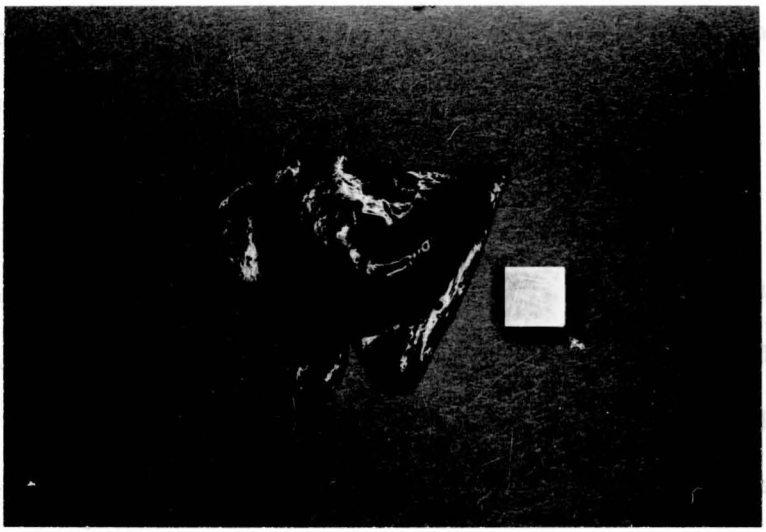

FIGURE 8

MEMBRANE AND REFERENCE SQUARE

E. Accuracy of the Technique Used

The accuracy of the applied technique was determined in the following manner. Several photographs were taken of the teeth, membranes, and reference square at various distances without refocusing. The distance between the object to be photographed and the camera was measured and recorded. The photographs were measured with a compensating polar planimeter and found to be directly proportional to the distance from which the photograph was taken.

The actual mathematical area of the reference square measured $25mm^2$. When measured with the compensating polar planimeter, it measured $24.6mm^2$. The discrepancy between the actual total area and measured total area was 1.6%. The reference square was made by the Cameron-Miller Instrument Company and according to the manufacture, its measurement was accurate to a $\pm$ .00015 of a mm.

F. Computation of Data

After all the measurements were recorded, the data was then transfered onto coding forms containing 20 columns. The first nineteen columns contained the measurements to be studied and the last column was used for card identification. Each line of the coding form represents one IBM punch card. Ninety IBM punch cards were used.

The IBM cards were punched according to the designated lines of the coding form. The punched cards were than placed into the IBM 1402 card reader and computed. The information contained on the cards was printed on the IBM 1403 line printer. The measurements on the cards were then verified to detect any possible error in the card punching.

CHAPTER IV

FINDINGS

Two values were obtained for each of the 180 Caucasion and Negro maxillary teeth used in the study. These values were, 1) projected root surface area and 2) total root surface area.

After measuring the square, membranes and projected areas of the teeth three times with a compensating polar planimeter, a total of 1080 measurements were recorded and more than 250 black and white photographs taken. These measurements were submitted to the computer center where they were punched, read and interpreted (Tables I thru VI).

The average total root surface area of the maxillary central incisor was 190.64 mm^2 for the Caucasion teeth and 201.95 mm^2 for the Negro teeth (Table I). The average total area of the Caucasion and Negro teeth combined was 196.5 mm^2.

The maxillary lateral incisor, as was expected, had the smallest total and projected root surface area for both the Caucasion and Negro teeth (Table II). The average area for the Caucasion tooth was 166.58 mm^2 snd 172.60 mm^2 for the Negro tooth. The combined average of the Caucasion and Negro teeth was 169.6 mm^2.

The maxillary canine had the second largest root surface area as

TABLE I

Maxillary Central Incisor

Tooth No.	Caucasion Teeth Projected Area mm^2	Caucasion Teeth Total Area mm^2	Negro Teeth Projected Area mm^2	Negro Teeth Total Area mm^2
1	75.6	205.3	71.1	166.7
2	79.6	221.0	71.3	172.5
3	83.5	231.5	72.4	194.0
4	70.4	190.5	90.1	261.2
5	72.3	212.3	72.5	201.5
6	61.6	185.7	73.3	181.1
7	62.5	181.0	85.3	249.2
8	61.4	166.3	90.8	239.0
9	71.5	195.5	82.5	203.2
10	64.5	181.0	81.7	219.3
11	71.7	186.3	70.2	194.1
12	56.0	145.7	73.7	206.7
13	78.3	211.0	69.7	207.3
14	69.4	185.5	61.0	164.0
15	68.0	161.0	63.2	169.5
Mean	69.75	190.64	75.25	201.95
Standard Deviation	7.37	22.30	8.62	29.02

TABLE II

Maxillary Lateral Incisor

Tooth No.	Caucasion Teeth		Negro Teeth	
	Projected Area mm^2	Total Area mm^2	Projected Area mm^2	Total Area mm^2
1	71.0	170.3	70.3	173.3
2	72.5	174.4	62.3	165.2
3	62.2	169.7	74.0	191.7
4	61.7	162.5	60.2	145.0
5	72.7	182.0	63.7	152.5
6	74.5	175.3	61.0	162.3
7	64.3	153.5	65.3	164.1
8	72.0	173.4	88.1	219.2
9	62.5	162.0	82.5	208.0
10	70.2	171.2	67.3	174.7
11	62.0	161.5	64.7	153.2
12	65.6	145.3	62.0	160.3
13	85.0	200.5	74.5	191.3
14	64.2	161.7	73.2	183.1
15	63.5	135.5	58.7	145.3
Mean	68.26	166.58	68.52	172.60
Standard Deviation	6.30	14.81	8.25	21.48

TABLE III

Maxillary Canine

Tooth No.	Caucasion Teeth Projected Area mm^2	Caucasion Teeth Total Area mm^2	Negro Teeth Projected Area mm^2	Negro Teeth Total Area mm^2
1	76.3	188.3	115.3	297.1
2	95.3	219.0	152.0	378.3
3	140.0	320.2	108.7	278.0
4	117.6	271.5	132.3	312.7
5	82.5	200.0	100.5	275.2
6	83.5	201.0	114.3	301.2
7	118.0	265.5	139.5	354.3
8	81.2	205.3	122.3	294.0
9	130.5	308.0	150.2	389.2
10	85.3	205.2	123.5	311.0
11	120.2	271.4	89.3	208.3
12	112.5	286.7	93.0	228.5
13	121.6	281.3	121.2	287.3
14	95.3	220.0	116.7	273.4
15	112.7	254.3	112.3	289.7
Mean	104.83	246.54	119.40	298.54
Standard Deviation	19.59	41.74	17.86	46.85

TABLE IV

Maxillary First Premolar

Tooth No.	Caucasion Teeth Projected Area mm^2	Caucasion Teeth Total Area mm^2	Negro Area Projected Area mm^2	Negro Area Total Area mm^2
1	91.5	214.3	125.1	328.4
2	122.7	315.0	105.3	272.3
3	130.0	348.7	95.0	226.5
4	96.3	263.4	95.7	249.2
5	97.5	304.5	131.0	299.0
6	84.3	231.0	112.0	321.3
7	105.0	242.3	105.7	283.1
8	103.5	247.5	87.3	231.5
9	106.4	206.4	107.5	251.7
10	75.0	185.7	120.3	324.3
11	83.3	184.5	91.5	228.5
12	75.3	181.3	111.7	274.3
13	79.5	267.0	105.3	245.0
14	73.5	156.5	114.0	257.2
15	105.0	251.0	113.3	248.7
Mean	95.25	239.94	108.04	269.40
Standard Deviation	16.64	52.52	11.85	33.79

TABLE V

Maxillary Second Premolar

Tooth No.	Caucasion Teeth		Negro Teeth	
	Projected Area mm^2	Total Area mm^2	Projected Area mm^2	Total Area mm^2
1	66.5	145.7	105.0	255.3
2	102.3	201.3	132.5	296.3
3	69.0	156.2	113.7	251.0
4	103.7	233.0	123.1	272.5
5	73.7	163.5	100.5	224.3
6	116.5	241.7	105.7	240.0
7	81.5	183.4	104.3	242.1
8	80.0	181.3	91.5	225.2
9	82.3	182.0	81.3	194.3
10	93.4	217.3	84.0	196.1
11	71.5	154.3	99.3	245.7
12	75.0	165.0	98.5	231.0
13	85.3	223.7	89.7	204.5
14	84.4	204.2	98.0	221.3
15	78.0	190.0	95.7	233.2
Mean	84.20	189.52	101.52	235.54
Standard Deviation	13.67	28.99	13.23	26.56

TABLE VI

Maxillary First Molar

Tooth No.	Caucasion Teeth Projected Area mm^2	Caucasion Teeth Total Area mm^2	Negro Teeth Projected Area mm^2	Negro Teeth Total Area mm^2
1	135.3	365.5	133.2	397.0
2	121.7	316.0	167.5	494.3
3	133.6	362.3	137.3	425.7
4	125.5	325.7	164.0	501.2
5	136.0	395.3	136.7	433.5
6	172.2	474.0	121.3	399.3
7	124.5	378.5	146.5	421.0
8	152.6	454.3	141.3	432.1
9	136.3	381.7	145.6	413.3
10	115.2	325.0	163.5	524.7
11	128.7	393.6	153.0	453.2
12	173.5	452.3	202.5	629.0
13	118.6	368.2	128.3	406.5
14	139.3	384.5	169.7	525.3
15	151.0	511.3	152.6	476.7
Mean	137.60	392.54	150.86	462.18
Standard Deviation	17.18	55.16	19.75	61.65

compared to the maxillary first molar which had the largest (Table III). The average area for the Caucasion tooth was 246.54 mm^2 and 298.54 mm^2 for the Negro tooth. The combined average value of these teeth was 272.5 mm^2.

The maxillary first premolar had the third largest root surface area and was slightly smaller than the canine. All first premolar teeth in this research had two roots (Table IV). The average area for the Caucasion tooth was 239.94 mm^2 and 269.40 mm^2 for the Negro tooth. The combined average value of these teeth was 254.6 mm^2.

The second premolar, 189.50 mm^2, had a smaller root surface area than the Caucasion central incisor 191.07 mm^2 and was larger, 235.54 mm^2, than the Negro central incisor which was 202.02 mm^2 (Table V). The combined average of both the Caucasion and Negro teeth was 212.5 mm^2.

The maxillary first molar as expected, had the largest root surface area of all the teeth measured. The Caucasion average of this tooth was 392.54 mm^2 and the average for the Negro tooth was 462.18 mm^2. The combined average of these teeth were 427.5 mm^2, (Table VI).

When the mean, standard deviation and 95% confidence limits were established, the mean averages were then designated variables, such as variable 1, variable 2, etc.

Variable 1 = the projected root surface area of the Caucasion teeth.

Variable 2 = the total root surface area of the Caucasion teeth.

Variable 3 = the projected root surface area of the Negro teeth.

Variable 4 = the total root surface area of the Negro teeth.

These variables were to be analyzed in all possible combinations to see if a correlation exists. They were arranged in two columns; Column A (independent variable column) and Column B (dependent variable column).

Column A (x)	vs	Column B (y)
Var. 1	vs	Var. 2
Var. 1	vs	Var. 3
Var. 2	vs	Var. 4
Var. 3	vs	Var. 4
Var. 4	vs	Var. 2

After arranging the variables in an orderly form the values were submitted to the IBM computer to determine the mean of x, mean of y, correlation coefficient, or x vs y, and the standard error of the estimate (Tables VII & VIII).

The accuracy and possible error of the computer was checked by arranging the variables in the following manner, var 2 vs var 4 and var 4 vs var 2.

The correlation values for the Caucasion total and projected root surface area ranged from a high of .980 for the canine to a low of .789 for the first bicuspid. The correlation values for the Negro total and projected root surface area ranged from a high of .966 for the lateral

TABLE VII

Correlation Coefficient

Maxillary Central Incisor

Variables x	Variables y	Mean of x	Mean of y	Correlation x vs y	Standard Error of the Estimate
Var 1	Var 2	69.753	190.640	.897	10.612
Var 1	Var 3	69.753	75.253	.333	8.740
Var 2	Var 4	190.640	201.953	.215	30.447
Var 3	Var 4	75.253	201.953	.882	14.681
Var 4	Var 2	201.953	190.640	.215	23.397

Maxillary Lateral Incisor

Var 1	Var 2	68.260	166.587	.793	9.706
Var 1	Var 3	68.260	68.520	.133	8.791
Var 2	Var 4	166.587	172.607	.373	21.409
Var 3	Var 4	68.520	172.607	.966	5.952
Var 4	Var 2	172.607	166.587	.373	14.768

Maxillary Canine

Var 1	Var 2	104.833	246.547	.980	8.857
Var 1	Var 3	104.833	119.407	.070	19.139
Var 2	Var 4	246.547	298.547	.030	50.306
Var 3	Var 4	119.407	298.547	.961	13.925
Var 4	Var 2	298.547	246.547	.030	44.825

TABLE VIII

Correlation Coefficient

Maxillary First Premolar

Variables x	Variables y	Mean of x	Mean of y	Correlation x vs y	Standard Error of the Estimate
Var 1	Var 2	95.253	239.940	.789	34.683
Var 1	Var 3	95.253	108.047	.323	12.050
Var 2	Var 4	239.940	269.400	.207	35.511
Var 3	Var 4	108.047	269.400	.784	22.547
Var 4	Var 2	269.400	239.940	.322	55.192

Maxillary Second Premolar

Var 1	Var 2	84.207	189.520	.897	13.796
Var 1	Var 3	84.207	101.520	.321	13.468
Var 2	Var 4	189.520	235.547	.068	28.468
Var 3	Var 4	101.520	235.547	.957	8.269
Var 4	Var 2	235.547	189.520	.068	31.073

Maxillary First Molar

Var 1	Var 2	137.600	392.547	.832	32.847
Var 1	Var 3	137.600	150.867	.123	21.062
Var 2	Var 4	392.547	462.187	.003	66.224
Var 3	Var 4	150.867	462.187	.960	18.574
Var 4	Var 2	462.187	392.547	.003	59.251

TABLE IX

Correlation Coefficients

x vs y

	Caucasion Total Area vs Projected Area	Negro Total Area vs Projected Area
Central Incisor	.897	.882
Lateral Incisor	.793	.966
Canine	.980	.961
First Premolar	.789	.784
Second Premolar	.897	.957
Molar	.832	.960

95% confidence limit ranged from .482 to .557

97% confidence limit ranged from .557 to .605

99% confidence limit ranged from .605 and above.

incisor to a low of .784 for the first bicuspid (Table IX). These findings indicate that the Caucasion central incisor, canine and first bicuspid have a higher confidence limit than the corresponding Negro teeth. The Negro lateral incisor, second bicuspid and first molar have a higher confidence limit than the corresponding Caucasion teeth.

CHAPTER V

DISCUSSION

The purpose of this project was to measure the total and projected root surface area of extracted maxillary teeth from the Caucasion and Negro population and to see if a correlation exists. If a correlation exists between two variables, this knowledge may be used in making reasonable predictions when only one of the variables is known. The unknown value could be predicted with a degree of certainty rather than assumed.

The standard values which have been obtained in this investigation will enhance the focus of attention upon root pressure as the important factor in determining the movement of teeth orthodontically. Root pressure is the important factor in determining tooth movement and not the force applied to the crown of the tooth.

The projected root surface area may be defined as that area of the tooth adjacent to the bone if the tooth is to be moved bodily in that direction.

It is noteworthy to mention that the total root surface area of a tooth is a tri-dimensional entity due to the convexities of the tooth, while the projected root surface area is bi-dimensional. Therefore,

the total root surface area is always larger than the projected root surface area. The total root surface area was measured using the membrane technique. A special photographing method was used to measure the projected root surface area.

The precision of this method can be attributed to several factors. Formvar can be air-cured in half the time it takes to cure polyvinyl chloride in an oven at 130° C. The pictures taken of the membrane and projected root surface areas were always taken with a fixed object to film distance. The reference square was used as a reference in every picture to obtain an exact magnification. Finally, the compensating polar planimeter is the most accurate instrument presently being used to measure the membranes and projected areas.

The values presented by this investigator substantiate the findings of Jepsen, Boyd, Moromisato and Emmanuelli. The result obtained by Tylman and Tylman (1960) and Freeman (1965), were considerably lower than those presented here. Tylman and Tylman presented a value of 139 mm^2 for the maxillary central incisor. This investigation yielded values of 191.07 mm^2 and 202.02 mm^2 respectively for the Caucasion and Negro maxillary central incisor (Table X).

Average values for the total root surface area of the Caucasion teeth were smaller than the average values for the root surface area of the Negro teeth, except for the central and lateral incisors which

TABLE X

Comparison of Total Root Surface Area Measurements
(mm^2)

Type of Tooth	Present 1968 Study Aver. Area Cauc.	Negro	Combined Aver.	Std. Dev. Cauc.	Negro	Moromisato 1967 Aver. Area	Jepsen 1962 Aver. Area	Tylman & Boyd Tylman 1960	1958	Freeman 1965
Central Incisor	191.07	202.02	196.5	22.3	29.0	209.4	204	139	204.5	23.0
Lateral Incisor	166.06	172.60	169.6	14.8	21.4	179.0	179	112	177.3	19.4
Canine	246.60	298.54	272.5	41.7	46.8	263.4	273	204	266.5	28.2
First Premolar	239.94	269.40	254.6	52.5	33.7	255.0	234	149	219.7	----
Second Premolar	189.50	235.54	212.5	28.9	26.5	215.1	220	140	216.7	25.4
Molar	392.54	462.45	427.5	55.1	61.6	438.3	433	335	454.8	53.3

were larger than the values presented by the above men. The two combined averages of the Caucasion teeth and the Negro teeth are closely related to the findings of these investigators. This was to be expected for their sample of teeth were obtained from a cross section of the general population whereas the teeth used in this research were separated into individual races.

Comparing the values between the Caucasion and Negro teeth revealed that the Negro teeth were larger than the Caucasion teeth both in the total and projected root surface areas. In their respective order, the first molar was the largest, than the canine, first premolar, second premolar, central incisor and the lateral incisor were the smallest. It was noted that the Caucasion second premolar was smaller than the Caucasion central incisor by 1.5 mm^2 and that the Negro second premolar was larger than the Negro central incisor by 33.5 mm^2.

When analyzing the results of the correlation x vs y, it was found that a correlation existed between var 1 vs var 2 and var 3 vs var 4. The results for these variables fell within a range of .784 to .980. These values were within the 99% confidence limit indicating significant correlations exist between the total and projected root surface area of the teeth. No correlation exists between any other combination of variables (Table IX).

One can predict with reasonable accuracy the total root surface area of any tooth in the maxillary arch from the central incisor to the first molar for the Caucasion and Negro teeth is the bucco-lingual projected root surface area is known. The results indicate that the ratio of total root surface area to bucco-lingual projected root surface area is rather constant between different types of teeth. The total root surface area of any tooth is approximately two and one-half times larger than its bucco-lingual projected root surface.

More emphasis should be placed upon the amount of force which is being used to move individual teeth. Orthodontic patients whether they be Caucasion, Negro or Oriental have been treated according to the same standards and force systems. This is prevalent in some teaching institutions even though the majority of their patients are Negro. If Negro teeth have a larger total and projected root surface area it would seem reasonable that a greater force should be applied when moving these teeth.

CHAPTER VI

SUMMARY AND CONCLUSION

A. Summary

A sample of 180 maxillary teeth were measured in this study. Ninety of these teeth were from the Caucasion population and ninety from the Negro population. Second and third molars were excluded from this study and all first premolars were birooted. The total root surface area was measured by using the membrane technique. Formvar was the material of choice because of its ease in handling and accuracy in measuring the root surface area. The projected root surface area of the teeth was measured by photographing the mesial surface of the roots and measuring from the photograph with a compensating polar planimeter.

The results of this investigation confirm the work of Jepsen, Boyd, Moromisato and Emmanuelli. These results do not agree with the values presented by Tylman and Tylman (1960) and Freeman (1965). Tylman and Tylman mentioned that their values were not accurate root surface area measurements but only figures which could be used as a comparison in future studies. Freeman used the membrane technique and the values he presented were much lower than those of any other investigator. Freeman arrived at a figure of 53.3 mm^2 for the total root surface area of a

maxillary first molar while this investigator revealed a value of 392.54 mm^2 for the Caucasion first molar and 462.45 mm^2 for the Negro first molar.

The mean values for the individual types of teeth were designated as variables and correlation coefficient relationships were established through the use of the computer. A significant correlation was found to exist between the total and projected root surface area of both the Caucasion and Negro teeth. It was only with the use of a computer that such a large number of correlation coefficients could be calculated. The correlation coefficients significant to the .01 level (99%) or higher are listed in Table IX.

B. Conclusions:

1. Original values have been established for the total and projected root surface area of teeth excluding second and third molars for both the Caucasion and Negro population.

2. The total and projected root surface area of the Negro teeth are larger than that of the Caucasion teeth.

3. A positive correlation exists between the total root surface area (var 1) and the projected root surface area of the Caucasion teeth

(var 2) and between the total root surface area (var 3) and the projected root surface area of the Negro teeth (var 4).

4. No correlation exists between any other combination of variables.

5. Data in the form of correlation coefficients and not ratios were calculated to establish relationships.

6. This work confirms the values of Moromisato, Emmanuelli, Jepsen and Boyd.

7. The total root surface area of a tooth was found to be approximately two and one-half times greater than the projected root surface area of the same tooth from the mesial aspect.

8. A reliable technique was devised in photographing the projected root surface area of these teeth.

9. The values and correlation coefficients established in this research may be useful in calculating the root pressure of teeth necessary for orthodontic tooth movement.

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APPROVAL SHEET

The thesis submitted by Dr. Stephen M. Matokar has been read and approved by members of the Departments of Anatomy and Oral Biology.

The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the thesis is now given final approval with reference to content, form and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the Degree of Master of Science.

May 21, 1968
Date

James G. Emerson
Signature of Advisor